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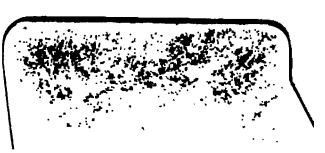
CHEMISTRY

IN

THE BREWING-ROOM

C. H. PIESSE



CHEMISTRY

IN

THE BREWING-ROOM:

BEING THE

SUBSTANCE OF A COURSE OF LESSONS TO PRACTICAL BREWERS.

WITH

TABLES OF ALCOHOL, EXTRACT, AND ORIGINAL GRAVITY.

BY

CHARLES H. PIESSE, F.C.S.

PUBLIC ANALYST.

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TO

W. E. SMITH, ESQ.,

ISLEWORTH,

This small Volume

IS DEDICATED

WITH THE KINDEST REGARDS OF

HIS FRIEND,

THE AUTHOR.

PREFACE.

THE matter contained in the following pages, being the *resumé* of a series of lectures delivered by me to classes of Practical Brewers, will be found to contain all that chemical matter, a knowledge of which is of value to the brewer. Moreover, this sort of matter has never before been collected and placed into tangible shape for the use of those for whom this work is designed; so that although no claim to novelty for most of the facts is set up, it is believed that the application of them is both new and useful.

O'Sullivan's investigation into the nature of the action of the diastase contained in malt, upon starch, led me to believe that the determination of the specific rotatory power of a wort might enable the operator to calculate the proportion of maltose and dextrin contained therein; but numerous observations and experiments have satisfied me that in most worts—and especially such as have been brewed from malt

entirely—the changes dependent upon temperature proceed with such rapidity as to vitiate for practical purposes this method of procedure.

The Table of the Speeific Gravities of Diluted Alcohol I have drawn up at considerable length, and is, I believe, all that can be desired for practical purposes; similarly, with the Table relating to the "Solid Extract." That one relating to original gravity is copied from the Report of the Commission, referred to in the chapter on Original Gravity of Worts. At the end will be found a Table of Weights and Measures, together with a few paragraphs, which, appertaining to the matter contained in the volume, will be found useful.

CHARLES H. PIESSE.

303 STRAND, LONDON, *May* 1877.

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CHEMISTRY

IN

THE BREWING-ROOM.

CHAPTER I.

DEFINITION OF TERMS.

1. SOLUTION.—This word is used by chemists to denote the union of a solid body with a liquid, which latter is called the solvent. A simple solution is one in which the substance remains in the free state, *i.e.*, not in combination with any other substance.

Example:—When a crystal of sulphate of copper (commonly called blue copperas) is placed into some water it rapidly dissolves, yielding a blue solution. If now the water be evaporated or dried off, the sulphate of copper will be left unaltered.

A chemical solution is one in which the substance dissolved does not retain the properties it before possessed; a chemical combination having taken place between the solvent and the substance dissolved, the solution possesses the properties

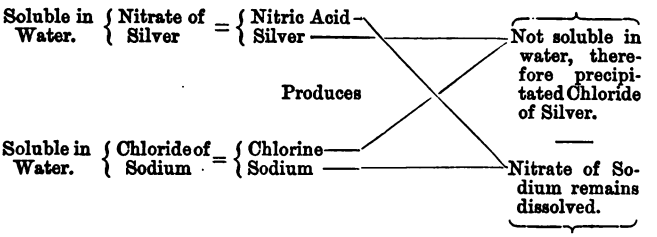
peculiar to the new substance produced or resulting from that combination.

Example:—A piece of metallic silver is dropped into some nitric acid contained in a test tube, the chemical action which occurs is manifested by the evolution of fumes and great extrication of heat. If the nitric acid be now evaporated, a new body called nitrate of silver is found, in which both nitric acid and silver exist, but in a condition totally different from each in its free state. When a gas is dissolved in a fluid, the act of solution is usually termed absorption, yet the product is referred to as a solution, thus: A solution of sulphurous acid in water means water which has absorbed sulphurous acid gas.

2. PRECIPITATION.—Is the term used to denote the operation of separating a solid body out of a solution generally by the addition of some other solution, without regard to the chemical composition of the precipitate (or substance separated), or to any of its physical properties, thus: If to a solution of nitrate of silver in water a solution of common salt (chloride of sodium), also in water, be added, precipitation immediately occurs, the silver by combination with the chlorine forms chloride of silver, which then and there separates by reason of its insolubility in water. Chemically speaking, it would be said "chloride of silver is precipitated" in this instance.

Precipitates.—The bodies separated from solution possess generally a composition intermediate between those of the substances from which they are formed. In the instance just referred to the action may thus be explained, and will

serve as an example of the reactions which occur in the formation of most precipitates.



Precipitates possess physical properties peculiar to themselves; thus they may be "crystalline," "gelatinous," "amorphous," &c., or they may be red, or yellow, or brown, &c., &c., according to their nature and constitution.

3. EVAPORATION.—Is the term applied to the operation of separating a solid (or non-volatile fluid) from a solution. It is generally conducted by placing the solution to be evaporated into a shallow dish, which is then heated, generally being placed upon a "water bath" (which see, p. 9), wherein the water is kept boiling, whereby the liquid or volatile portion of the solution is converted into vapour, and thus dissipated, whilst the solid or non-volatile body remains unaltered in the dish.

4. DECANTATION.—Is applied to the act of pouring off a solution from above a precipitate or other solid body in a liquid.

5. FILTRATION.—Is the operation of passing a liquid in which some solid matter is suspended mechanically, e.g.,

a precipitate, through a piece of porous paper, suitably folded and placed upon a funnel. The filter paper is cut circular, and then folded in four by twice folding across the centre, the second fold being at right angles from the first. In certain special cases, substances other than paper may be made use of for filtering, these are, wool, asbestos, charcoal, &c., &c.

6. CRYSTALLISATION.—Is the act of separating a solid in the particular crystalline shape peculiar to it from a liquid. It is effected by very slow evaporation, generally without any application of heat to the solution. For further information on the subject of crystals, consult "Bristow's Mineralogy," "Watt's Dictionary of Chemistry," article *Crystallography*, or any *Encyclopædia* under the same heading.

7. DISTILLATION.—Is the process used to separate a volatile fluid from a solid body, or from a less volatile, or non-volatile fluid, in such manner as to recover the evaporated or more volatile liquid (compare with "Evaporation," page 3). It is usually conducted by placing the liquid to be distilled into a retort or flask connected with a condenser, and then boiling the liquid in the flask, and collecting the condensed liquid, or distillate, in a suitable receiver. The term sublimation is used instead of distillation when a solid body is separated by heating from a non-volatile one.

8. FUSION.—Means bringing a solid body into the fluid state by heating it.

9. IGNITION.—Is the process employed to separate one

solid substance from another where it is desired to retain the non-volatile one, thus: In the case of a wort or beer the ash may be obtained by igniting the residue left, after evaporating a portion of the liquid.

Explanation of Apparatus.

Beakers are glass vessels made of thin well-annealed glass, in which solutions are held, and heated when necessary, and in which precipitations, &c., are effected. They are made of all sizes—for the purposes of the operations hereafter mentioned, about 24 will be requisite, which should consist of two to hold about 48 ozs., four of 2 to 4 ozs., the remainder being of about 12 to 15 ozs. capacity each. Those provided with a "lip," or spout, are most desirable. They are generally sold in "nests," *i.e.*, series of about eight in number.

Watch Glasses are concave glasses made to fit, and just overlap the beakers which they are intended to cover. At least one for each beaker will be requisite.

Burettes are graduated cylindrical tubes of about $\frac{5}{8}$ inch wide, and 18 inches long, which narrow at the bottom extremity so as to admit of an indiarubber tube being fixed upon them; into the other end of the indiarubber tube a hollow glass point is introduced, the space between the end of the burette and the glass point admits of being closed by a pressure clamp. The burettes are made to deliver measured quan-

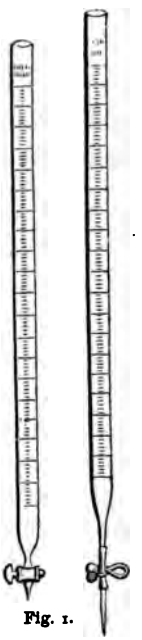


Fig. 1.

tities of the solutions with which they are filled by simply opening the clamp. Fig. 1 (Burettes).

The Clamp for closing the bottom of the burette is a curved brass spring. One for each burette will be required—see Fig. 2.

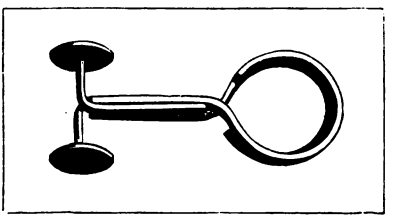


Fig. 2.

Pipettes are tubes for measuring small but definite quantities of fluids. The smaller should have the form represented by fig. 3 *a*, the larger by *b*; the limit of the capacity of each is marked by a "nick" on the upper tube of each. One each of 5, 10, 25, and 100 septems, one each to deliver 10, 25, 45, and 100 grain measures, and of 5, 10, 25, and 50 c.c.

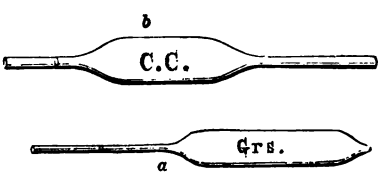


Fig. 3.

Measuring Flasks are used for measuring larger bulks of fluids, and should be made of thin well-annealed glass. One each of 500, 1000, 10,000, and 7000 ($\frac{1}{10}$ gallon) grains required.

Graduated Glass Cylinders are frequently useful, particularly in the manufacture of "standard" solutions, *i.e.*,

solutions of known strength. Two of these will be found sufficient.

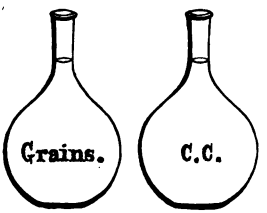


Fig. 4.

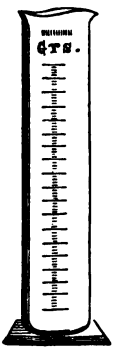


Fig. 5.

Gas Lamps for heating by gas. The best are those invented by Bunsen, and called "Bunsen burners." They

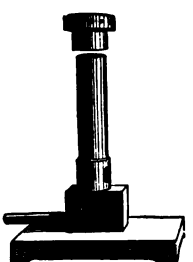


Fig. 6.

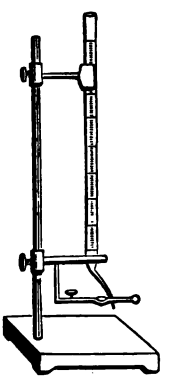


Fig. 7.

are air-gas burners, and so produce only a blue flame, which heats without making black the objects heated.

Where gas cannot be obtained, spirit lamps must be used. Three should be enough.

Stands for Burettes are wooden or metal uprights on a foot, and provided with a claw, or with suitable means for holding burettes when in use. They are made ready fitted with a screw clamp, so that no other is necessary for closing the burette. This latter form is very useful, and is called "Percy's Burette Stand." One for each burette will be required. (Fig. 7.)

Wash Bottle. By the means of this apparatus precipitates which have been filtered are freed from adhering solution; which is effected by throwing a small stream of distilled water upon them a considerable number of times, taking care to allow each addition of water to entirely filter before adding a further quantity. The wash bottle consists of a glass flask, fitted with a cork perforated with two holes; through one hole passes a glass tube which reaches to the bottom of the flask, the upper part projecting through the cork is bent over rather more than a right angle, and is drawn out to a point. Through the other hole a tube passes to just below the bottom of the cork, the upper extremity being bent to rather less than a right angle. Now if some water be placed into the flask, and the cork with tubes fitted in, on blowing through the shorter tube the water will be forced up the longer one and out at the point; the stream of water can thus be directed at will. Three of these, each of 1½ pints capacity, will be *sufficient.*

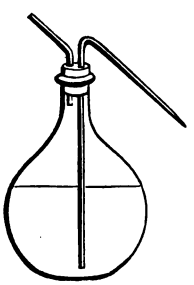


Fig. 8.

Water Bath. This is a copper vessel fitted with a series of concentric rings at the top, so that they will support objects of various sizes, and prevent the too free escape of the steam when the water is boiled; on the water bath evaporations are conducted. One capable of holding about one quart of water will be enough.

Fig. 9.

Retort Stands. Three of various sizes, each with three arms, and each with a "universal" clamp.

Test Tubes. These are thin glass tubes closed at one end. Used for testing small quantities of substances. *Test Tube Brushes* for cleaning the tubes must also be obtained, as well as a rack to hold the test tubes, as shown in the figure.

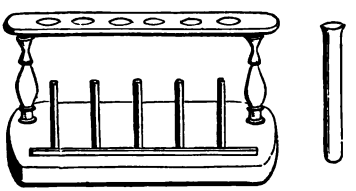


Fig. 10.

Tripods.—Three-legged iron stands on which to place objects or things to be heated, *i.e*, the water-bath, the air-bath, the drying-oven, &c., &c. Six, each about 8 inches high, will be sufficient.

Wire Gauze.—This is used to place upon the tripod when a beaker or flask containing fluid is to be heated. It prevents the flame from playing up the sides of the vessel. Two square feet will be enough when cut up as required.

Evaporating Dishes are thin shallow porcelain vessels, which are used as their name implies, for evaporation. Six should be obtained, four of which should hold 15 to 20 oz., the other two to hold about 2 oz. each. An evaporating dish of platinum will also be requisite, it should hold about 6 fluid oz.

Retort and Condenser.—A particular instrument, specially made for the distillation of beers, &c., is manufactured, and is requisite for the accurate determination of alcohol in beers. It is known as "Phillips' Revenue Standard Still."

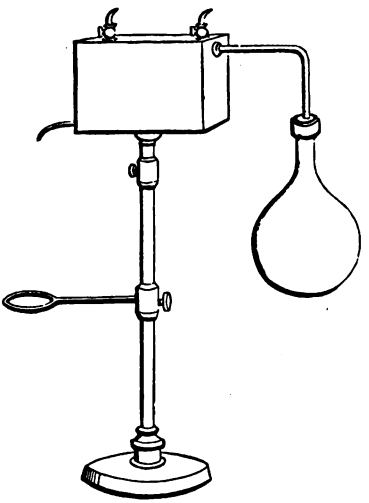


Fig. 11.

Glass Rods, for stirring liquids, are requisite. They may be bought ready-made, or in lengths which may readily be cut to any size, by scratching the rod transversely with a triangular file. Their sharp edges may be rounded off by holding them for a few moments in the point of the flame of the Bunsen burner.

Files.—Small triangular, and circular (called rat-tailed), files, will be found indispensable.

Cork Borers are hollow brass cylinders, sharpened to a circular knife edge at one end, and are used for cutting holes through corks.

Filter Paper.—The best, called "Swedish," may be bought ready cut into circular pieces of various sizes.

Flasks.—Several flasks will be required. They are the same shape and make as the graduated flasks, but not being graduated are cheaper.

Funnels.—The shape of a funnel is known to every one. *For chemical* purposes they are made of glass.

Funnel Stands, or filter stands, are wooden uprights on a foot. On the upright is an arm adjustable to any height by a screw, at the end of the arm a bevelled circular hole is cut vertically. They support the funnels over beakers or other vessels during filtration.

Water Oven.—This is a copper vessel consisting of an inner box or case surrounded on five sides with an outer jacket. On the sixth side is a door opening into the inner case. Through the top is a hole into the inner case, which permits of the exit of the water evaporating from the substance being dried. Also at the top, but in one corner, is a hole through which the space between the cases can be filled with water, and the steam produced by boiling the water can escape. The use of this apparatus is to dry substances at the temperature of boiling water, which above that temperature would be decomposed.

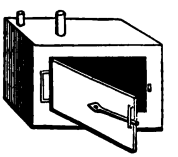


Fig. 12.

Air Bath.—An iron box, through a hole in the top of which a thermometer passes, the bulb being inside. The thermometer is supported by a cork fitting the hole, and bored so as to allow the passage of the thermometer, without being so loose as to permit it to slip. This is for drying substances, at temperatures somewhat above the temperature of boiling water.

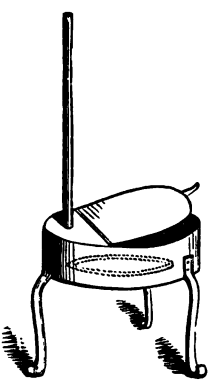


Fig. 13.

Desiccator, used for allowing hygroscopic substances to cool in dry air previous to weighing them (the extract of beer, for

example). It consists of a bell-glass fitting on to a glass slab. Beneath the bell-glass is a shallow vessel containing strong sulphuric acid, covered with a lid of perforated zinc or wire gauze.

Balance and Weights.—It is important that a tolerably good balance should be in the possession of every one called upon to perform chemical operations. For the whole of the purposes hereinafter mentioned, a balance that will indicate, when loaded to its utmost (which should be about 4 oz.), a weight of $\frac{1}{20}$th of a grain, and which will turn to $\frac{1}{40}$th or $\frac{1}{50}$th of a grain, with 2 oz. or less upon the pans, would be sufficiently accurate. The beam of the balance should be divided into ten divisions, each indicated by a notch or line, and each of those divisions subdivided into two. These divisions serve to indicate the weight of the "rider," a small wire bent to the form shown in the cut, which when placed upon the pan weighs 0·1 grain, but which indicates a less weight when placed across the beam, the amount of the diminution being directly proportional to its proximity to the centre. The weights must consist of the following series, which are generally made in brass:—Grains, 600, 300, 200, 100, 60, 30, 20, and 10, and of the following, which are generally made of platinum, 6, 3, 2, 1, 0·6, 0·3, 0·2, 0·1, 0·06, 0·03, 0·02, 0·01, and several "riders." The weights must be moved with pincers (included in the box containing the weights) for the purpose, and must never be touched with the hands. A set of gram weights should be obtained also.

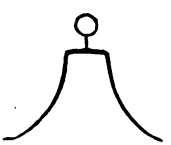


Fig. 14.—"Rider."

Specific Gravity Bottle.—This is a very carefully adjusted *bottle, made to contain* a definite weight of distilled water at

a given temperature. The size usually made contains from 500 to 700 grains at 60° Fahr. The counterpoise (which is the weight of the bottle empty) must be verified before use.

Thermometers for chemical purposes are usually made with an enamel back, the degrees being marked upon the stem of the thermometer, no back or support is required.

Hydrometers.—These instruments for chemical purposes are made to indicate the actual specific gravity of the liquids in which they float, instead of "pounds per barrel," &c., the basis upon which they are usually manufactured for brewers.

Hydrometer Immersiors are tubes precisely resembling the graduated cylinders (page 7), save that they are not graduated.

Quantitative Watch Glasses are rather thick watch glasses, with their edges ground flat horizontally, so that when two are placed together, with their convexities outwards, they form a slight hollow glass box. They are held together by a suitable brass clamp.

The foregoing are necessarily but brief descriptions of certain pieces of apparatus which form but a small proportion of those constantly in use in the chemical laboratory, but, being all that are required in the performance of the experiments described, all others have been purposely omitted. The more detailed accounts are to be found in any of the numerous handbooks of chemistry, among which "Fownes' Manual" stands prominent.

CHAPTER II.

THE GENERAL EXAMINATION OF WORTS AND BEERS.

For all practical purposes the examination of a wort or beer may be limited to the estimation of the amounts of sugars (saccharine), albumen, extract, alcohol, ash, and chlorine in the ash. It being a matter sometimes of importance in the brewing of beers to obtain a wort which shall contain relatively a large proportion of its saccharine ingredients in the form of dextrine (which, while imparting body to the wort or beer, gives to it also its keeping qualities by reason of its non-fermentability), and sometimes the converse the estimation of the actual amounts of fermentable and of non-fermentable extract in any particular wort becomes one of some importance also; but the accurate estimation of the sugars in such a solution as a wort is a problem demanding the utmost skill of the practical analyst, and therefore one which cannot well be considered within the province of the brewer. Neglecting, therefore, extreme accuracy, we may confine our attention to such practical methods of discriminating between the sugars as those by which results can be obtained, which are sufficiently accurate for all ordinary purposes, by which it is meant that the actual quantities of fermentable and of non-fermentable sugars may be estimated to

within about a per cent.; these determinations being as near to true accuracy as are the determination of density or dry solid extract by the brewers' hydrometers. The results may therefore be expressed in either of the following ways:—1. Fermentable and non-fermentable extract; or 2. as dextrine and fermentable sugars. The "total solid extract" contained in both worts and beers is practically the measure of the carbohydrates—dextrine, dextrose, maltose—present in those liquids; but the accurate determination of the amounts of each of those bodies, when all three are present, is attended with such difficulties that it may be considered as practically impossible.

O'Sullivan has shown * that the action of extract of malt upon starch, which has been gelatinised with hot water, is to convert it into maltose and dextrine, the relative proportions of those bodies produced being dependent upon the temperature, and the length of time during which the action is allowed to proceed; the longer the time and higher the temperature, the greater the amount of maltose.

A very small quantity of the malt extract being sufficient to convert a large proportion of starch; for example, the extract obtained by treating 10 grams of malt with cold water, and filtering the solution, completely converted 100 grams of starch, yielding 70 per cent. of maltose and 30 per cent. dextrine in five or six minutes. The relative amounts of these two bodies was determined by means of the saccharimeter—an instrument for measuring the amount of rotation which the plane of a ray of polarised light suffers on passing through a solution of an optically active substance, of known strength and given thickness (width)—

* Journal Chemical Society for August 1876.

and calculating the ratio from the known specific rotatory power of each.

The same observer found, by direct experiment, that prolonged heating of the gelatinised starch, with even such a small proportion of malt extract as that mentioned, effected the gradual conversion of the maltose into dextrose, or more probably into two or more varieties of dextrose, whose distinguishing characteristics are as yet not made out.

In a wort, therefore, made entirely from malt, in which the ratio of the transforming agent to the starch is manifestly so much greater than in the cases of the experiments referred to (*loc cit*), it will be evident that a large proportion of the maltose at first produced is soon changed into the dextrose.

The specific rotatory power, *i.e.*, the angle of rotation produced in the plane of the polarised ray by a 10 per cent. solution, one metre thick,—of maltose is 150°, that of dextrine 214°; the mean of that of the dextroses is 67°.

It will at once be seen from the fact, that at least three optically active bodies—assuming the existence of only one dextrose—are present in wort; no estimation of the quantity of each present can be made by the determination of the optical activity.

When glucose (which is dextrose *par excellence*) is heated to the boiling point for a few minutes with a re-agent called Fehling's Liquid, which consists of a solution of sulphate of copper, Rochelle salt,* and caustic potash—the sugar causes the precipitation of suboxide of copper; 100 parts of dextrose precipitate, in this way 198·5 parts of the suboxide; the

* Rochelle salt is tartrate of potash and soda.

dextrose from maltose behaves in a manner precisely similar; maltose precipitates only 65 per cent as much; and dextrine is without action.

This reaction would afford a method of determining the amount of each of these bodies if only two were present in the liquid, but it will be at once understood that since all three must of necessity be present, this method is also unavailable. Under the circumstances, therefore, of these accurate methods being inapplicable, recourse must be had to mere approximative means, which serve simply to discriminate between "fermentable" and "non-fermentable" portions of the extract. Two of such means are available, namely:—

I. Precipitation of the dextrine.
II. Fermentation.

The term "non-fermentable" is used here merely in a comparative sense. The substance referred to is wholly fermentable in the course of time, by the gradual conversion of the dextrine into maltose and dextrose; but it is not fermented to any sensible extent by exposure to the action of yeast for about 12 hours.

Process I.

The exact specific gravity of the wort is first taken by weighing, and the amount of total solid extract it contains found by means of the table (p. 28).

A small beaker capable of holding about 80 to 100 cub. cents. (3 ozs.), after being thoroughly cleaned and dried, is carefully weighed, about 3 to 5 cub. cents. of the wort poured

into it, and the weight again taken; the exact weight of the wort employed is thus obtained.

Very strong alcohol, to the extent of 15 or 20 times the bulk of the wort, is then added, and the beaker, after being covered with a watch-glass, allowed to stand for about 24 hours. At the end of that time the whole of the precipitated dextrine will have collected to a mass firmly adhering to the bottom of the beaker. The supernatant alcohol is then poured off, the dextrine rinsed with strong alcohol, and finally dried by standing the beaker in the heated water oven. It is then weighed; and in order to ensure that the dextrine is perfectly dry, it is again heated as before, for a short time, and after cooling, again weighed; if it has lost weight the drying process must be repeated until the weight is constant. From the weight so found, that of the empty beaker must be deducted, the remainder is the weight of the dextrine. The proportion which it bears to the total dry extract may then be calculated, as in the following example:—

Specific Gravity of Wort.

(The empty specific gravity bottle is exactly counterpoised by a brass weight adjusted for the purpose.)

Weight of water contained by the bottle, 24·980 grams.
Weight of an equal bulk of the wort, . 27·007 grams.

$$\frac{27{\cdot}007}{24{\cdot}980} = 1{\cdot}0811$$

By the table, a specific gravity of 1·0811 corresponds to 21·1 per cent of dry extract.

Precipitation of the Dextrine.

Weight of beaker + wort, .	33·608 grams.
„ „ empty, .	28·535 „
„ Wort employed, .	5·073
Weight of beaker + dextrine, .	28·945
„ „ empty, . .	28·535
Dextrine found, . . .	·410

Dry extract in wort employed.

$$100 : 21{\cdot}1 :: 5{\cdot}073 : x = 1{\cdot}0704$$

Dextrine found.

$$1{\cdot}07 : 0{\cdot}41 :: 21{\cdot}1 : x' = 8{\cdot}1$$

and $21{\cdot}1 - 8{\cdot}1 = 13$.

The 21·1 per cent. of total dry extract consists therefore of

Dextrine, ...	8·1
Fermentable extract, . .	13·
	21·1

This process scarcely gives results of more than approximative accuracy, the dextrine found being generally 2 or 3 per cent. short of that actually present, as shown by the fermentation process, which is more reliable. It may be possible that some modification of dextrine exists in worts, which is neither precipitable by alcohol nor fermentable; or that the water in which dextrine is dissolved may retain the power of holding some dextrine in solution, even when extended *ad*

infinitum with alcohol, although the dextrine itself may be completely insoluble in alcohol. Better analytical results may, however, be obtained if the beaker containing the weighed quantity of wort be placed standing over strong sulphuric acid in a dessicator for twenty-four hours or more before the precipitation of the dextrine. A considerable proportion of the water being thereby evaporated, the separation of the dextrine is more perfect.

The weight of the albumen precipitated along with the dextrine need not be taken into account, since it will scarcely ever exceed ·001 gram. on the quantity of wort employed.

In all cases great care must be taken to completely remove adhering sugar, by repeatedly washing the separated dextrine with strong alcohol before finally drying and weighing it.

Process II.—Fermentation.

The principle upon which this method is based, is the fact that both dextrose and maltose ferment when treated with yeast, and thereby yield alcohol and carbonic acid, while dextrine is practically not acted upon. The amount of alcohol produced being definite for a given weight of the fermentable sugar; by determining the amount of alcohol yielded by the fermentation of a quantity of wort containing a known amount of extract, it is evident that the quantity of sugar from which the alcohol was derived may be calculated. The difference in the percentage, between the sugar so found and the total extract, may be considered as dextrine, or "non-fermentable extract."

When glucose sugar is fermented, it yields 51·1 per cent. *of its weight of* alcohol. Maltose is converted by the

fermenting agent into glucose before the fermentation proceeds, which conversion consists in the assimilation of one molecule of water by each equivalent of the maltose sugar. This yields, therefore, the same percentage of alcohol as the final action, but the actual percentage is manifestly greater when it is calculated from the atomic weight of the maltose, as will be seen by the following. The chemical formula of glucose is $C_6 H_{12} O_6$, and each equivalent of this splits up into two equivalents of alcohol and two equivalents of carbonic acid, thus:—

$$C_6 H_{12} O_6 = \begin{cases} C_2 H_6 O - \text{alcohol.} \\ C_2 H_6 O - \text{alcohol.} \\ C \quad O_2 - \text{carbonic acid.} \\ C \quad O_2 - \text{carbonic acid.} \\ \hline C_6 H_{12} O_6 \end{cases}$$

The atomic weight of a compound atom is found by multiplying the number of atoms of each of the elements present by the atomic weight of the element, and adding the products together.

Thus, in the case of glucose—

$$\begin{aligned} C_6 &= 6 \times \overbrace{12}^{\text{At. w. of carbon.}} = 72 \\ H_{12} &= 12 \times \overbrace{1}^{\text{At. w. of hydrogen.}} = 12 \\ O_6 &= 6 \times \overbrace{16}^{\text{At. w. of oxygen.}} = 96 \\ & \qquad\qquad\qquad 180 = \text{at. w. of glucose.} \end{aligned}$$

By the same process the atomic weight of alcohol is found to be 46. But by the formula it is shown that the atom of glucose yields two atoms, or 92 parts of alcohol; where from the following proportion is obtained for calculating the percentage of alcohol to be got from 100 parts of glucose.

$$180 : 92 :: 100 : x$$
$$x = 51{\cdot}1$$

In the same way with the maltose, the formula of which is $C_{12}\ H_{22}\ O_{11}$, and the atomic weight 342. This assimilates one molecule of water H_2O (thereby becoming $C_{12}\ H_{24}\ O_{12}$), and splits up into four atoms of alcohol, and four of carbonic acid. That is to say, that 342 parts of maltose give rise to the formation of 184 parts of alcohol, from which its percentage yield may be calculated thus:—

$$342 : 184 :: 100 : x$$
$$x = 53{\cdot}8$$

This difference in the percentage of alcohol yielded by the two different sugars is not too great to prevent the employment of the fermentation method for obtaining an approximative estimation of the fermentable extract contained in a wort, where the alcohol found by experiment may be calculated as though derived entirely from glucose.

The process may be carried out as follows:—Weigh out into a counterpoised beaker about 70 grams, or 1000 grains of the wort, noting the exact weight. Pour it into a gauged flask of say 500 cub. cents, or 7000 grains capacity; rinse *out the beaker,* and add the washings also to the flask, and

pour in water equal to twice or three times the bulk of the wort. Add then a small quantity of fresh yeast, free from alcohol, and by shaking thoroughly mix it with the diluted wort; cover the flask with a watch glass, and let it stand in a warm place at a temperature of 60° F.—70° F. for 12 or 18 hours. When the fermentation is completed, the bulk of the liquid is made up to a definite amount by adding distilled water up to the indicated capacity of the flask. The whole of the liquid is then transferred to a retort connected with a condensing arrangement, and about one-third to one-half of the bulk distilled over. The distillate, after being made up to the same bulk as that of the original liquid, is carefully mixed so that it may be uniform throughout, and the specific gravity of it then taken by weighing. The whole operation of distillation, and taking the specific gravity of the distillate, is performed exactly as in the estimation of the alcohol in beers (which see). From the specific gravity, calculate, by means of the Table of Alcohol (see *Beer*), the amount of absolute alcohol present in the whole bulk of the fluid before distillation, and from that calculate the amount of glucose to which it is equal.

It has, however, been found that in practice the whole of a sugar submitted to fermentation is not converted into alcohol and carbonic acid as represented in the equation, but that a quantity, amounting to about four per cent. of the whole, is converted into various other bodies, amongst which glycerine is the most abundant. A correction must therefore be made at this stage to compensate for the loss thus occurring, which correction consists in calculating an increase of four per cent. on to the amount of sugar found by experiment. Deduct the total thus found from that of the total solid

extract (previously determined) in the wort under examination; the remainder is the "non-fermentable" extract.

The following example will make the explanation clear:—

Estimation of the Fermentable Sugar by direct Fermentation.

Specific gravity of wort, 1·0811 (see *Dextrine*).

Weight of wort employed for the experiment, 64·472 grams.

(Dry extract therein, 13·6.)

After fermentation the bulk was made up to 350 cub. cents; about 150 cub. cents were distilled over, and then the bulk of the distillate was extended by the addition of water to 350 cub. cents.

Specific gravity of that diluted distillate found by experiment, 0·9979.

Alcohol corresponding to that specific gravity (by Table), 1·124 per cent.

Total alcohol in the 350 cub. cents therefore, 3·924.

Sugar (glucose) calculated equal to total alcohol, .	7·68
Add four per cent., ...	·307
Total sugar,	7·987

Extract in wort used.

Therefore 13·6 : 7·987 :: 21·1 : 12·39

Therefore the 21·1 per cent. of total solid extract is made up of:—

Fermentable extract, . . .	12·39
Non-fermentable, by diff., . .	8·71
	21·10

ESTIMATION OF THE ALBUMIN.

The method of determining the amount of albumin in a wort is simply as follows. Filter a quantity of the sample (or, if it is free from sediment or suspended matter, this filtration may be dispensed with), and measure into a capacious beaker say 5000 grains of the filtrate; boil it for about 15 minutes, and then filter the coagulated albumin on to a counterpoised or weighed filter. This is then thoroughly washed with hot distilled water, dried in the water-oven, and again weighed. The increase on the weight of the filter-paper only is the amount of albumin contained in the quantity of the sample used, from which it may be calculated to any desired denomination. The filter-paper to be used should be folded so as to lie on a watch glass, and placed for twenty minutes into the water-oven; it is then to be placed in the dessicator till cool (so as to prevent it from absorbing moisture from the air), and finally rapidly weighed. The amount of albumin in beers is very small, reaching only about twenty grains per gallon; in worts, as would be inferred, it is somewhat larger. The sugar, dextrine, and albumin may be estimated in beers by precisely the same processes as those just described for worts.

CHAPTER III.

THE ESTIMATION OF THE TOTAL SOLID EXTRACT AND THE ASH.

PLACE a water bath filled with tap water upon one of the tripods, and under it place a lighted lamp. Carefully weigh a platinum basin, and put it on to the water bath; let it be held by as large a "ring" as will safely hold it, in order to expose as large a surface as possible to the direct heat of the steam. Measure into a measuring flask exactly 1000 grains of the sample, which pour into the platinum dish so that this latter is about two-thirds full; if the whole of the measured quantity would more than fill the basin to that extent, allow that much to evaporate off before adding the remainder; finally wash the flask out with distilled water, and transfer the washings to the platinum basin. When the evaporation has proceeded as far as possible over the water bath, transfer the platinum basin with the residue to the air bath, in which the thermometer is registering a temperature of about 35° or 40° Fah. above the boiling point of water, that is to say, 245° to 250° Fah., since water boils at 212° of that scale. After the residue has been kept at that temperature for about 45 to 60 minutes, it may be considered to be dry. Transfer it to the dessicator until it is cool, and then rapidly weigh it. *The weight thus* noted, minus the weight of the platinum

basin alone, is the weight of the total solid residue, which multiplied by 70 gives the result in grains per gallon, or divided by 10 gives it in a percentage. To determine the ash, place the platinum basin with residue on a pipe-clay triangle, mounted upon a tripod; apply heat, gently at first, and finally more intensely until the whole of the combustible portion of the residue is burnt off; cool the platinum basin in the dessicator and weigh again. The weight, minus the weight of the platinum basin, shows the amount of ash in the quantity of the sample used; it may be brought into grains per gallon by multiplying it by 70, as in the case of the whole of the residue. The estimation of the quantity of chlorine in the ash affords a method of detecting cases of the adulteration of the beer by the addition of common salt (see page 53). But a still easier method of ascertaining the amount of dry extract contained in the wort is to take its specific gravity by means of the hydrometer, and then to consult the table given on page 28, bearing in mind that if very minute accuracy is desired, the percentage of ash must be deducted from the percentage of dry extract found as corresponding to the specific gravity indicated.

For determining the amount of extractives in beer, the de-alcoholised liquor remaining after the estimation of the alcohol in beers (which see) may be employed for general purposes; although, for very accurate work, the bulk of the beer employed, instead of the weight, must be ascertained, and the bulk of the liquor after boiling to expel the alcohol must be restored by the addition of water instead of its weight. The correction for the ash contained in the beer must be also made as in the case of worts.

TABLE,

Giving percentage of dry extract by weight in volume of liquid corresponding to the specific gravities indicated.

Specific Gravity.	Percentage of Dry Extract.	Specific Gravity.	Percentage of Dry Extract.	Specific Gravity.	Percentage of Dry Extract.
1·0040	1·004	1·0115	2·908	1·0185	4·710
1·0045	1·130	1·0120	3·036	1·0190	4·840
1·0050	1·256	1·0125	3·164	1·0195	4·970
1·0055	1·383	1·0130	3·292	1·0200	5·100
1·0060	1·509	1·0135	3·420	1·0205	5·230
1·0065	1·635	1·0140	3·549	1·0210	5·360
1.0070	1·762	1·0145	3·677	1·0215	5·490
1·0075	1·889	1·0150	3·806	1·0220	5·621
1·0080	2·016	1·0155	3·935	1·0225	5·751
1·0085	2·143	1·0160	4·064	1·0230	5·882
1·0090	2·270	1·0165	4·193	1·0235	6·013
1·0095	2·397	1·0170	4·322	1·0240	6·144
1·0100	2·525	1·0175	4·451	1·0245	6·275
1·0105	2·652	1·0180	4·581	1·0250	6·406
1·0110	2·780				
1·0235	6	1·0617	16	1·1033	26
1·0274	7	1·0655	17	1·1071	27
1·0313	8	1·0693	18	1·1108	28
1·0351	9	1·0731	19	1·1146	29
1·0389	10	1·0769	20	1·1183	30
1·0427	11	1·0807	21	1·1221	31
1·0465	12	1·0845	22	1·1258	32
1·0503	13	1·0921	23	1·1296	33
1·0541	14	1·0928	24	1·1332	34
1·0579	15	1·0996	25		

REMARKS.—Intermediate numbers may be obtained by interpolation.

CHAPTER IV.

THE ESTIMATION OF THE ALCOHOL IN BEERS.

ONE method of estimating the amount of the alcohol in beers is remarkable for its simplicity. The results obtainable by it, though not exact to scientific accuracy, are yet sufficiently so for all the purposes required in the brewery. It necessitates the use of an accurate balance, capable of carrying a greater weight than the one described on page 12, and yet giving indications to the $\frac{1}{10}$th of a grain. It is as follows:— First take the specific gravity of the sample by means of the hydrometer, being careful to bring the temperature of the liquid to exactly 60° Fah. before doing so. Note the specific gravity. Then weigh accurately say 7000 grains of the beer in a beaker, and transfer it to a capacious flask; rinse out the beaker with the smallest possible quantity of water, and add that to the bulk. Place the flask with the beer on to a tripod, which is covered with a piece of wire gauze, and place a lighted lamp beneath it. Let the beer boil for about half an hour, or until about $\frac{1}{8}$th of its bulk has evaporated, whereby practically the whole of the alcohol is driven off; now cool the flask and re-transfer its contents to the beaker, and add distilled water until the weight is again equal to that of the beer before boiling; see that its temperature is 60° Fah., and then take the specific gravity again. Since the specific gravity of the unboiled beer is less than that of

the boiled beer in exactly the same proportion as the specific gravity of a diluted alcohol is less than the specific gravity of water, it is only necessary to adopt the following rule for finding the specific gravity of a diluted alcohol of the same strength as the beer.

RULE.—Divide the specific gravity of the unboiled beer by the specific gravity of the boiled beer (after this has been made up to its original weight by the addition of distilled water). The following example will illustrate the method :—

Specific gravity of unboiled beer, . . 1·0255
Specific gravity of boiled beer, . . 1·0361

$$\frac{1{\cdot}0255}{1{\cdot}0361} = {\cdot}98976.$$

From the specific gravity thus obtained, the percentage of alcohol can be found by reference to the following table of the percentages by weight of absolute alcohol contained in diluted alcohol of different specific gravities.

TABLE,

Showing the percentage of absolute alcohol by weight, and by volume, and as proof spirit, in diluted alcohols of the following specific gravities at 60° Fah.

Specific Gravity.	Absolute Alcohol by Weight.	Absolute Alcohol by Volume.	Per centage of Proof Spirit.	Specific Gravity.	Absolute Alcohol by Weight.	Absolute Alcohol by Volume.	Per centage of Proof Spirit.
1·0000	0·00	0·00	0·00	·9965	1·89	2·36	4·16
·9999	0·05	0·07	0·11	·9960	2·17	2·71	4·77
·9995	0·26	0·33	0·57	·9955	2·45	3·07	5·39
·9990	0·53	0·67	1·17	·9950	2·74	3·43	6·02
·9985	0·80	1·00	1·76	·9945	3·02	3·78	6·63
·9980	1·07	1·33	2·36	·9940	3·32	4·14	7·29
·9975	1·34	1·67	2·95	·9935	3·61	4·50	7·92
·9970	1·61	2·00	3·54	·9930	3·90	4·86	8·55

Specific Gravity.	Absolute Alcohol by Weight.	Absolute Alcohol by Volume.	Per centage of Proof Spirit.	Specific Gravity.	Absolute Alcohol by Weight.	Absolute Alcohol by Volume.	Per centage of Proof Spirit.
·9925	4·20	5·23	9·20	·9705	20·91	25·36	44·81
·9920	4·51	5·62	9·88	·9700	21·31	25·82	45·63
·9915	4·82	6·00	10·55	·9695	21·69	26·30	46·43
·9910	5·13	6·38	11·22	·9690	22·08	26·80	47·23
·9905	5·45	6·77	11·92	·9685	22·46	27·27	48·03
·9900	5·77	7·17	12·61	·9680	22·85	27·73	48·83
·9895	6·09	7·58	13·30	·9675	23·23	28·18	49·63
·9890	6·42	8·00	14·02	·9670	23·62	28·64	50·41
·9885	6·75	8·42	14·73	·9665	24·00	29·09	51·21
·9880	7·09	8·83	15·47	·9660	24·38	29·55	52·01
·9875	7·43	9·25	16·20	·9655	24·77	30·00	52·80
·9870	7·78	9·66	16·95	·9650	25·43	30·56	53·55
·9865	8·13	10·08	17·71	·9645	25·50	30·98	54·29
·9860	8·48	10·50	18·46	·9640	25·86	31·52	55·24
·9855	8·84	10·91	19·23	·9635	26·20	31·80	55·73
·9850	9·20	11·36	20·01	·9630	26·53	32·18	56·39
·9845	9·56	11·82	20·78	·9625	26·87	32·58	57·09
·9840	9·92	12·27	21·55	·9620	27·21	32·97	57·78
·9835	10·35	12·73	22·47	·9615	27·57	33·33	58·41
·9830	10·81	13·18	23·47	·9610	27·93	33·81	59·25
·9825	11·23	13·64	24·36	·9605	28·25	34·18	59·90
·9820	11·62	14·10	25·17	·9600	28·56	34·54	60·53
·9815	12·00	14·60	26·00	·9595	28·87	34·89	61·14
·9810	12·39	15·09	26·82	·9590	29·20	35·27	61·81
·9805	12·77	15·55	27·64	·9585	29·53	35·65	62·47
·9800	13·15	16·00	28·46	·9580	29·86	36·03	63·14
·9795	13·54	16·50	29·28	·9575	30·17	36·39	63·77
·9790	13·92	17·00	30·10	·9570	30·44	36·70	64·32
·9785	14·33	17·50	31·03	·9565	30·72	37·01	64·86
·9780	14·75	18·00	31·99	·9560	31·00	37·33	65·42
·9775	15·17	18·50	32·91	·9555	31·31	37·69	66·05
·9770	15·58	19·00	33·78	·9550	31·62	37·91	66·44
·9765	16·00	19·50	34·66	·9545	31·94	38·40	67·30
·9760	16·42	20·00	35·46	·9540	32·25	38·76	68·03
·9755	16·83	20·50	36·37	·9535	32·56	39·11	68·54
·9750	17·25	21·00	37·13	·9530	32·87	39·46	69·15
·9745	17·66	21·50	38·01	·9525	33·18	39·81	69·77
·9740	18·08	22·00	38·87	·9520	33·47	40·14	70·34
·9735	18·46	22·45	39·67	·9515	33·76	40·47	70·92
·9730	18·85	22·91	40·48	·9510	34·05	40·79	71·48
·9725	19·25	23·40	41·33	·9505	34·29	41·06	71·96
·9720	19·66	23·90	42·20	·9500	34·52	41·41	72·39
·9715	20·08	24·40	43·07	·9495	34·76	41·59	72·88
·9710	20·50	24·90	43·94	·9490	35·00	41·84	73·32

In the event of a specific gravity being experimentally obtained which is not marked in the table, the quantity of alcohol corresponding to it may easily be calculated by the process of interpolation, a mathematical operation which is thus conducted. Find in the table given above the two specific gravities nearest to that obtained in the experiment—the one greater, the other less than it—and the quantities of alcohol corresponding to them. Subtract the less specific gravity from the greater; let the difference stand as the first term of a proportion. Subtract the less quantity of alcohol from the greater; let the difference stand as the second term of the proportion. Subtract the specific gravity obtained by experiment from the greater specific gravity above referred to, and let the difference stand as the third term of the proportion; then the fourth term, obtained by working out the proportion, is the difference between the less quantity of alcohol above referred to and that corresponding to the specific gravity found by experiment. Therefore it is only necessary to add those two amounts together to ascertain the amount of alcohol exactly corresponding to the specific gravity obtained experimentally.

The following example will make the explanation clear:—

A.	Specific gravity obtained by experiment, . .	·9979
B.	Specific gravity next above it in the table, .	·9980
b.	Alcohol corresponding to it in the table, . .	1·07
C.	Specific gravity next below it in the table, .	·9975
c.	*Alcohol* next below it in the table, . . .	1·34

$$\overbrace{B}^{\cdot9980} - \overbrace{C}^{\cdot9975} = \overbrace{D}^{\cdot0005}$$

$$\overbrace{c}^{1\cdot34} - \overbrace{b}^{1\cdot07} = \overbrace{d}^{\cdot27}$$

$$\overbrace{B}^{\cdot9980} - \overbrace{A}^{\cdot9979} = \overbrace{E}^{\cdot0001}$$

Then $\overbrace{D}^{\cdot0005} : \overbrace{d}^{\cdot27} :: \overbrace{e}^{\cdot0001} : \overbrace{e}^{\cdot054}$

$$\overbrace{b}^{1\cdot07} + \overbrace{e}^{\cdot054} = \overbrace{x}^{1\cdot124}$$

x = Alcohol corresponding to the specific gravity obtained by experiment.

The results obtainable by this method are more exact for beers containing comparatively little extract than for those containing a comparatively large quantity. To obtain results of rigid accuracy, another method must be resorted to, viz., that of distillation, in which the alcohol is distilled from a *weighed* quantity of beer, the specific gravity of the distillate then taken with the precautions described, and from it the amount of alcohol originally contained in the beer calculated.

The following brief description of the process and of the distilling apparatus may be found useful. Pour about a pint and a half of the sample into a capacious flask, and vigorously shake it to expel the carbonic acid, then weigh out say 7000 grain measures (by first counterpoising a 7000 grain measure flask, then filling up to the index and weighing), and transfer this weighed quantity to a distilling

flask or retort; connect it with a condenser which is kept cool by a running stream of water, and distil about half of the beer. The distillate is collected in a graduated flask capable of holding 7000 grain measures; the bulk of the distillate made up to that measure by the addition of distilled water, and the whole cooled (after thoroughly mixing) to 60° F. A portion of this is then placed into the specific gravity bottle and accurately weighed. (If the bottle is not counterpoised separately, its actual weight empty must be first deducted from the weight of alcohol plus the bottle.) On dividing the weight thus found by the weight of water which the bottle holds (both weighed at 60° F.), the quotient will be the specific gravity of the alcohol. The quantity of alcohol corresponding to it, either by weight, volume, or as proof spirit, is then found by means of the table given at page 30, and is the actual quantity of alcohol contained in the amount of beer operated upon, from which it may be readily reduced to a percentage, or to any other denomination desired, either by weight or volume.

CHAPTER V.

ON ORIGINAL GRAVITIES.

On all beers exported from this country a considerable drawback is allowed on the duty paid, on account of the alcohol contained therein; and as the calculations for this drawback are based on the specific gravity of the wort before fermentation, *i.e.*, the *original gravity*, it is highly necessary for the operator to have in his possession a ready means of determining from the beer itself the specific gravity of the original wort used in its manufacture. Now starch-sugar yields, when submitted to the action of yeast-ferment, as nearly as possible, half its weight of alcohol,* so that the operation would be an easy one if the extract consisted solely of that substance; for having given the quantities of extract and alcohol in a beer, it would simply require the weight of the alcohol to be doubled and added to the extract, then the sum of the two would represent the specific gravity of the original wort.

But as the dextrine—produced from the decomposition of the starch by the action of diastase when in the mash-tun—cane-sugar, which is added to the mash by some brewers, caramel, albuminoids, glycerine, various salts, &c., are constituents of the extract, and whose solutions have each different specific gravities, the problem becomes a more

* See *ante*, page 20, *et seq.*

complicated one. For instance, a 20 per cent. solution of starch-sugar has a specific gravity of 1088, while solutions of the same strength of cane-sugar, caramel, dextrine, and of an extractive matter containing glycerine and succinic acid, have respectively the specific gravities 1084·0, 1072·0, 1067·5, and 1072·7. The albuminoids and salts of the earths and alkalies unavoidably present do not practically interfere with the specific gravity. It will be, therefore, seen that the simple process just referred to is inapplicable where anything like accuracy is required. If any of the alcohol had been derived from cane-sugar, the results would indicate a gravity higher than the true original gravity, since weight for weight cane-sugar furnishes on fermentation more alcohol than starch-sugar. Again, because a portion of the fermentable sugar is converted into inert extractive matter, a lower original gravity would be indicated.

To meet these various difficulties two methods have been devised, which, although of a purely empirical nature, are sufficiently exact in their results to satisfy all practical requirements. They owe their origin to Messrs. Hofmann & Redwood and the late Professor T. Graham; these observers experimentally fermented solutions of starch-sugar, cane-sugar, and malt extract of known specific gravities, and at several stages of the fermentation made the following experiments and observations:—From a measured quantity of the fermenting liquid they distilled (in a manner similar to that subsequently to be described, p. 39) the alcohol, diluted the distillate with water to the volume of that of the liquid taken for the experiment, took its specific gravity, and subtracted that from the specific gravity of water. The difference *was a number* which they termed the *spirit indication* of that

liquid they were experimenting on. The portion of the liquid remaining undistilled was cooled, and diluted with water up to its original bulk, its specific gravity then taken, and this (called the extract gravity) subtracted from the original specific gravity of the liquid before it was fermented: the numbers thus obtained indicated the degrees of "gravity lost," or the extract that had been converted by fermentation into alcohol, carbonic acid, &c., and corresponded in a certain manner with the *spirit indication.*

From the results of a large number of these experiments, with some modifications, the following tables were constructed:

TABLE I.—To be used in ascertaining Original Gravities by the Distillation Process.

DEGREES OF SPIRIT INDICATION WITH CORRESPONDING DEGREES OF GRAVITY LOST IN MALT WORTS.

Degrees of Spirit Indication.	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	...	0·2	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·2	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	27·0	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	58·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	70·5									

TABLE II.

To be used in ascertaining Original Gravities by the Evaporation Process.

Degrees of Spirit Indication, with corresponding Degrees of Gravity lost in Malt Worts.

	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	...	0·3	0·7	1·0	1·4	1·7	2·1	2·4	2·8	3·1
1	3·5	3·8	4·2	4·6	5·0	5·4	5·8	6·2	6·6	7·0
2	7·4	7·8	8·2	8·7	9·1	9·5	9·9	10·3	10·7	11·1
3	11·5	12·0	12·4	12·8	13·2	13·6	14·0	14·4	14·8	15·3
4	15·8	16·2	16·6	17·0	17·4	17·9	18·4	18·8	19·3	19·8
5	20·3	20·7	21·2	21·6	22·1	22·5	23·0	23·4	23·9	24·3
6	24·8	25·2	25·6	26·1	26·6	27·0	27·5	28·0	28·5	29·0
7	29·5	30·0	30·4	39·9	31·3	31·8	32·3	32·8	33·3	33·8
8	34·3	34·9	35·5	36·0	36·6	37·1	37·7	38·3	38·8	39·4
9	40·0	40·5	41·0	41·5	42·0	42·5	43·0	43·5	44·0	44·4
10	44·9	45·4	46·0	46·5	47·1	47·6	48·2	48·7	49·3	49·8
11	50·3	50·9	51·4	51·9	52·5	53·0	53·5	54·0	54·5	55·0
12	55·6	56·2	56·7	57·3	57·8	58·3	58·9	59·4	59·9	60·5
13	61·0	61·6	62·1	62·7	63·2	63·8	64·3	64·9	65·4	66·0
14	66·5	67·0	67·6	68·1	68·7	69·2	69·8	70·4	70·9	71·4
15	72·0									

The numbers in the first column of these tables represent the integers of the *spirit indication*, and those in the top row the decimal fractions of the same; the figures in the other columns are the degrees of gravity lost, corresponding with the various spirit indications. With the aid of these tables and the spirit indications, obtainable by either of the two methods respectively now to be fully described, the *original gravity* of any beer is calculated.

The Distillation method :—

Into a moderately capacious flask, say about 400 to 500 c.c. fitted to a Liebig or other suitable condensing arrangement, place 200 c.c. of the beer whose original specific gravity it is desired to know, distil over into a 200 c.c. measuring flask from 100 to 120 c.c. This will contain all the alcohol.

The distillation must be at first proceeded with cautiously, as the dissolved carbonic acid and albuminoids in the beer cause it to froth up in a somewhat unmanageable manner. However, after the gas is expelled, the ebullition continues quietly enough.* When the distillation is finished, the distillate in the flask is diluted up to the original bulk of the beer, with distilled water, shaken in order to well mix the fluids, and its specific gravity taken by means of a specific gravity bottle. The number thus obtained, if subtracted from 1000, the specific gravity of water, will give the spirit indication.

The boiled beer remaining in the flask is cooled, transferred to a measuring flask and diluted up to 200 c.c. (the original volume of the beer), and its specific gravity taken. This will be the extract gravity.

If now the degrees of gravity lost, found in table (I.) corresponding to the spirit indication, be added to the extract gravity, the sum of the two will represent the original specific gravity of the wort from which the beer was fermented.

An example will probably render the explanation clearer. Thus :—

Specific gravity of water, ...	1000·0
Suppose the specific gravity of the distillate to be	993·1
The spirit indication will then be . .	6·9

* The addition of half a grain of tannin will almost completely prevent this *frothing*, and will not make any perceptible difference in the extract *gravity*.

Now, on referring to Table I., there will be found on the same line as the integer 6, and in the last column, viz., that under figure 9, the number of degrees of gravity lost corresponding to this spirit indication, namely, 28·3.

This added to the extract gravity will give the original specific gravity of the wort before fermentation. Thus :—

Extract gravity, ...	1018·9
Gravity lost (Table), ...	28·3
Original gravity, ...	1047·2

The other method of determining the original gravity, known as the evaporation method, although less accurate in its results, is far more expeditious. It may happen that the operator has not the necessary manipulative skill, or the time at his disposal to conduct a distillation; the following plan may then be used, thus :—Briskly agitate in a large flask, in order to deprive it of the dissolved carbonic acid, some of the beer under examination, and determine its specific gravity. Boil a known quantity of it, say 100 c.c., until it is reduced about half in volume, by which time the alcohol will be expelled, allow it to cool and dilute with distilled water again to 100 c.c., and take its specific gravity, which will be its extract gravity. Divide the specific gravity of the beer before boiling by that after boiling, and subtract the quotient from 1000, the result will be the spirit indication. Find in Table II. the number of degrees of gravity lost, and add them to the extract gravity, whereby the original gravity of the wort before fermentation is obtained.

For example:—

Specific gravity of beer before boiling, . 1022·1

„ „ „ after „ . . 1031·4

$\frac{1022·1}{1031·4} = 990·9$, 1000—990·9 = 9·1

By Table II. the gravity lost corresponding to a spirit indication of . . . . . 9·1 = 40·5

Add the specific gravity of beer after boiling = 1031·4

Original gravity, therefore, . . . 1071·9

CHAPTER VI.

THE EXAMINATION OF WATERS.

THE question of the qualities of the waters used in brewing is one of undisguised importance, as doubtless every brewer is aware. There are certain points in the analysis of waters which cannot well be decided by other than skilled chemists: these are the determination of the amount of contamination which a water has suffered from the introduction of sewage and the like organic impurities, the amount of nitrates and the complete investigation of the nature of the mineral substances held in solution in the water. But there are certain other points of considerable moment which can be decided with tolerable accuracy by any person acquainted with only such an amount of chemical manipulation as these pages will bring under their notice, and which every practical brewer certainly ought to be able to perform. These are the detection of the presence of nitrites and an approximate determination of their amount, the detection of the presence of nitrates, of the presence and amount of chlorine (which may be calculated wholly as sodium chloride, or common salt), of the amount of total solids (*i.e.*, mineral matters, with an approximate idea of the quantity of total solids which consist of organic substances), and of the total and permanent hardness, *this latter* serving to indicate the amount of sulphate of

lime, together with the quantities of carbonate of lime and carbonate of magnesia which remain dissolved in the water even after it has been boiled, communicating the property of "permanent hardness," which is generally accepted as being beneficial to a water used for brewing.

THE DETECTION AND APPROXIMATE ESTIMATION OF THE AMOUNT OF NITRITES.

This depends upon the fact that when a solution of a nitrite is mixed with starch-paste, acetic acid, and potassium iodide, this latter is decomposed, and the iodine which is liberated at once combines with the starch to form a compound (iodide of starch) of an intensely blue colour; therefore, when using a specific bulk of the water to be tested, and comparing the intensity of the blue coloration produced with that produced by a known quantity of a nitrite in an equal bulk of distilled water, an approximate estimation of the amount of nitrite present in the water under examination may be made. The solutions required are first prepared in the following manner (it is advisable to make a quantity of each to be kept in stock) :—

1. *The potassium iodide solution.* Dissolve 240 grains of potassium iodide in 10 oz. of distilled water.

2. *Make a thin paste of pure starch,* with distilled water, by boiling say 1 oz. of starch with 10 oz. of water, and allow it to cool.

3. *Pure commercial glacial acetic acid,* diluted with about an equal bulk of distilled water.

4. *Standard solution of potassium nitrite.* Dissolve 0·7 grains of dry potassium nitrite in 1000 grains of distilled

water. If 10 grain measures of this be added to 1000 measures (this quantity should be really 990 measures, but this slight difference may be disregarded in practice) of distilled water, that will then contain an amount of nitrite equal to 0·5 grain per gallon.

To test a water for nitrites. Put into a beaker capable of holding about 1500 grains 3 septems of the potassium iodide solution, a like bulk of the starch-paste, and say 9 septems of the diluted acetic acid, then add 1000 grains of the water to be tested. Note the amount of blue coloration developed in one hour. Anything more than a mere trace of coloration would indicate such an amount of nitrite as to practically condemn the water. To estimate the amount of the nitrite repeat the experiment with the water to be tested, and in another beaker mix the same quantities of the reagents, make up the bulk to 1000 grains with distilled water, and add to it 10 grain measures of the standard solution of potassium nitrite. If the amount of coloration developed is equal in each the amount of nitrites is also equal, viz., 0·5 grain per gallon. If the amount of coloration be unequal repeat the experiment with the distilled water, adding more or less of the standard solution of potassium nitrite according to the indication obtained, until the coloration is equal in each. The amount of standard solution of potassium nitrite employed will be the measure of the quantity of nitrite in the water. So little as 0·5 grains of nitrite per gallon of water is very detrimental, the action of the nitrite being to set up that sort of secondary fermentation in the beer brewed from such water, known technically as "fretting." It is advisable to test the purity of the reagents by making a "blank" experiment, *i.e.*, mixing them in the proportions indicated with

1000 grains of distilled water. No coloration should ensue, but if any is produced it is probably due to impurity in the potassium iodide.

Nitrates may be tested for thus:—Place a porcelain basin on a tripod over a very small gas (or spirit) flame, and pour into it about 2000 grains of the water; let it evaporate down to about 100 grain measures, and pour that into a clean test tube; when it is cool, put into it a crystal of sulphate of iron (green copperas), and when that has completely dissolved, pour down the side of the test tube, with a gentle, steady motion, about 50 grain measures of strong sulphuric acid; this will sink to the bottom, and at the juncture of the two liquids a brown ring will be produced, due to the reduction of the nitrates in the water. The quantity and intensity of the brownness affords some indication of the greater or less abundance of the nitrates.

Chlorine. This is estimated by means of a standard solution of nitrate of silver, and the process is based upon the fact that if a solution containing a chloride and a chromate, the nitrate of silver being added, the whole of the chlorine is removed first, before the chromate is affected. The chloride of silver is white; the chromate of silver is red: therefore, if the solution of nitrate of silver be very gradually added, till the appearance of the red chromate of silver (which at first is removed by shaking) becomes permanent, it is a sign that the whole of the chlorine is removed, and the quantity of the standard solution of nitrate of silver employed to effect this becomes the measure of the quantity of chlorine present in the solution. In practice, care must, of course, be taken that only the smallest possible permanent red tint be communicated to the liquid under examination by the solution of

nitrate of silver, in order that the amount of chlorine be not erroneously over-estimated. To estimate the chlorine in a water the two following reagents will be required:—

1. *Standard solution of silver nitrate.* Dissolve 0·479 grains of pure nitrate of silver in 70,000 grains (1 gallon) of distilled water. Every septem measure of this solution is equal to 0·0001 grain of chlorine, or ·0001662 grain of common salt (chloride of sodium). The number of septems of this solution required to precipitate the chlorine in 700 grain measures of the water to be tested is the number of 1-10ths of a grain of chlorine per gallon. The number of grains of chlorine per gallon multiplied by 1·662 = grains of common salt.

2. *Solution of yellow potassium chromate.* Dissolve 70 grains of yellow potassium chromate in 700 grains of distilled water. The quantity of chlorine (or of common salt) contained in a water may now be estimated thus:—First, fill the burette to the zero with the standard solution of silver nitrate. Place into a beaker 700 grains (*i.e.*, 100 septems) measure of the water to be tested, and add 2 septems of the solution of chromate of potash. Then slowly drop into it the standard solution of silver nitrate from the burette, whilst keeping the water in the beaker constantly stirred until a slight permanent red coloration is produced. The number of septems of the standard solution of silver nitrate used is the number of 10ths of a grain of chlorine per gallon of water. If the quantity of chlorine per gallon be multiplied by 1·662, the result will express the quantity of common salt to which the chlorine found is equivalent.

It is advisable to keep some standard solution of silver nitrate ten times stronger than that mentioned, to be used if

a water is found to contain a considerable proportion of chlorine, or where great accuracy in the results is not required.

Total Solids, &c.

The amount of total solids contained in a water may be ascertained in the following manner:—Let a platinum dish capable of holding about 1500 grain measures (first perfectly cleaned, then heated to redness to completely dry it, and then cooled)* be accurately weighed, then placed upon the water-bath, and 1000 grain measures of the water poured into it. When the water has wholly evaporated, transfer the dish to the air-bath, and heat it to about 250° F. for five minutes; cool the dish as before, and weigh it again. The increase in weight multiplied by 70 shows the number of grains per gallon of water. If the dish be now heated to redness for a few moments, cooled, and again weighed, the loss in weight which the residue will have suffered is due almost wholly to organic matter. Its amount should be calculated into grains per gallon, as in the case of the total residue, by multiplying by 70. This estimation of the loss on ignition is, as a rule, but of little value, but in waters exceptionally contaminated with organic matter the amount of charring which occurs on igniting the residue, and the odour it evolves, may afford some criterion or sort of crude test.

Hardness.

The hardness of a water is the measure of its soap-destroying power; and the determination of the hardness is effected

* This cooling is well effected by allowing the dish to stand for a few moments upon a mass of cold iron, say a common flat iron without a handle, as recommended by Wanklyn and Chapman in their "Water Analysis."

by measuring the quantity of a standard solution of soap in alcohol required to form a lather when shaken with a measured quantity of the water under examination. The standard solution of soap is made of such a strength that each septem (or cub. cent.) is equal to 1° of hardness in the presence of 700 grain measures (or 70 cub. cent.) of water, the basis of the standard being that the "degree" of hardness is the hardness produced by one grain of carbonate of lime, or to an equivalent amount of any other salt of lime or magnesia per gallon of water—(0·0143 grams per litre). The requisite solutions are prepared in the following manner:—1. The standard solution of 16° of hardness. This is most conveniently made by dissolving 27·52 grains of selenite* in one gallon of water (0·393 grams per litre). The selenite should be crushed to very fine powder before the quantity required is weighed out, it will then dissolve without difficulty. 2. The standard solution of soap is made by dissolving a small piece of soft soap, weighing about 180 grains (12 grams) in about 150 c.c. of strong alcohol. This solution is then filtered and mixed with its own bulk of distilled water (or even more, so long as it does not give a froth or lather on being shaken), and the bulk of the whole increased about sixfold by the addition of proof spirit (alcohol of 50 per cent.).

The strength of this diluted solution of soap is then determined by means of the standard solution of selenite in the following manner:—Measure accurately 10 septems (or 10 cub. cent.) of the soap solution, and put it into a glass-stoppered bottle of about 6 oz. capacity, and add 90 septems (or

* Selenite is crystallised sulphate of lime, and the quantity here directed to be used is that which is equivalent to 16 grains of carbonate of lime.

60 cub. cents.) of distilled water. Shake the mixture so as to produce a lather. From a filled burette, then gradually add the standard solution of selenite until frothing stops, care being taken to thoroughly shake the bottle between each addition of every half septem (or half cub. cent.) of the selenite solution. From the result of this experiment calculate how much the soap solution must be diluted in order to make 17 septems (or 17 cub. cents.) of it equal to 16 septems (or 16 cub. cents.) of the solution of selenite, in the presence of 83 septems (or 54 cub. cents.) of distilled water: dilute a measured quantity of the solution of soap accordingly, with proof spirit in the proportion indicated by the result of the calculation. Each septem of the soap solution will then be equivalent to 1° hardness in the presence of 100 septems of water; or each cub. cent. is equal to 1° of hardness in the presence of 70 cub. cents. of water: that is to say, that if 100 septems (or 70 cub. cents.) of a water be placed into a bottle, and the standard solution of soap gradually added from a burette previously filled up to 0 or zero, the mixture being duly shaken between each addition, then the number of septems or cub. cents. respectively requisite to first produce a permanent lather is the number of degrees of hardness of the water. The hardness, therefore, may be considered as representing the number of grains of carbonate of lime in a gallon of water.

If in the determination of the hardness of a water it be found that the 100 septems (or 70 cub. cents.) of the water require more than 17 septems (or 17 cub. cents.) of the standard solution of soap to produce a lather, 100 septems (or 70 cub. cents.) of distilled water must be added; and to make allowance for the soap consumed in producing a lather with

the quantity of distilled water added (it being evident that *some* soap must be thus required), from the total number of septems (or cub. cents.) of soap solution now used to produce a lather "1" must be subtracted: the remainder indicates the hardness of the water. Should the water, however, even when thus diluted, require more than 34 septems (or cub. cents.) of the standard solution of soap, a further quantity of 100 septems (or 70 cub. cents.) of distilled water must be added, and "2" subtracted from the number of septems (or cub. cents.) now required to produce a lather. The remainder as before indicates the hardness of the water. In the performance of the experiment upon a sample of natural water, between each addition of soap the bottle must be stoppered and vigorously shaken, so as to thoroughly incorporate the soap solution with the water, and then, on removing the stopper, the air contained in the bottle must be sucked out by means of a piece of glass tube, so as to replace it with fresh air. The careful addition of the soap solution, and agitation of the contents of the bottle, must be continued, until a lather, which lasts for several minutes without dispersion, is produced; but, of course, the greatest care must be taken not to add more of the soap solution than is just sufficient to produce the lather, for otherwise the hardness will, it is evident, be over-estimated.

The degree of hardness thus determined is called the *total* hardness of the water.

When an ordinary water is boiled, the bicarbonate of lime and of magnesia held in solution are decomposed, and the resulting carbonates are precipitated, thus diminishing the hardness.

The hardness of a water after half an hour's boiling is the

permanent hardness. The difference between it and the total hardness is called the *temporary* hardness.

The permanent hardness of a water is determined in precisely the same way as the total hardness, but the sample is previously subjected to boiling in the following manner:— Measure out in a gauged flask 500 septems, or any similar bulk of the water, transfer it to a common flask capable of holding about double that amount, and boil it for about half an hour. Cool the water, and filter it into the original measuring flask, and make up with distilled water the amount lost by evaporation during the boiling. The hardness of the water after this treatment is its permanent hardness.

CHAPTER VII.

METALS.

POTABLE waters sometimes contain traces of certain metallic substances which injuriously affect the character of the water, *e.g.*, lead, copper, iron.

The two former are practically only likely to occur in such waters as are delivered through leaden pipes for household purposes, or are stored in tanks arranged with the well-known automatic tap and floating copper ball.

To test a water for such metallic contamination, about 6 or 8 ounces of it should be placed into a tall glass cylinder, standing upon a sheet of white paper, and about 3 or 4 ounces of water saturated with sulphureted hydrogen added. A brown coloration ensuing in the course of twenty minutes would indicate the presence of either (or both) of those metals. Their amount may be determined by the depth of the colour on comparison with like bulks of "standard" waters containing known amounts of lead treated in a similar manner. The experiment, however, is not one to be recommended in unskilled hands, on account of the evil odour of the reagent to be employed.

Iron.—This metal sometimes occurs in well waters; these, on exposure to the air for more or less time, become coated with a film of the iron salt, separating in a basic form, and

acquire a cloudy appearance. Occasionally some hydrated oxide of iron, which separates as a brownish sediment, gets into the water, being derived from the iron pipes through which the water passes. To test a water for iron, some of it should be acidified in a glass vessel, with pure strong hydrochloric acid, and then a few drops of a solution of sulphocyanide of potassium, or of ferrocyanide of potassium added. If iron be present, the former will cause a blood-red coloration, the latter, a blue (or greenish, if the quantity of iron be very minute), which ultimately settles as a blue precipitate.

Both lead and copper, if present in detectable quantities, render the water injurious, since they are both poisonous, and both cumulative in the system. Iron affects the brightness and keeping qualities of beers brewed from waters containing it.

CHAPTER VIII.

ESTIMATION OF THE CHLORIDES IN THE ASH OF BEER.

THE ash from the 1000 grain measures of beer, which had been obtained in the determination of the solid extract and ash (see page 26), is heated with about 300 grain measures of distilled water, and allowed to stand for about half an hour. It is then carefully stirred, and filtered through a small filter paper, the filtrate being collected into a 1000 grain-measure flask. The basin is then carefully rinsed into the funnel, by means of the jet from the wash bottle, and the washing of the filter paper, and the insoluble substances contained in it, continued until the filtrate measures 1000 grains. The filtrate is then transferred to a beaker, some potassium chromate added to it, and the standard solution of silver nitrate then added in the manner and with the precaution indicated for the estimation of the chlorine in water (which see page 45). The quantity of chlorine thus found, multiplied by 70, gives the number of grains of chlorine per gallon, and, as before stated (page 46), that product multiplied by 1·662, gives the amount of common salt to which the chlorine is equivalent. It may be considered as established that the chlorine thus found exists actually as sodium chloride, but the proof that it is so, as shown by a complete analysis of the residue, can, of course, only be effected by a

trained analytical chemist. By the law it is held that a beer may contain not more than 50 grains of sodium chloride per gallon; any quantity in excess of that amount is considered to have been fraudulently added, for the purpose of adulteration. The estimation of the chlorine affords, therefore, a simple and rapid method of determining whether or not a beer contains more than the amount of common salt permitted by law.

APPENDIX.

PART I.

WEIGHTS AND MEASURES.

480	grains Troy	= 1 oz. Troy.
5760	,,	= 1 lb. ,,
437·5	,,	= 1 oz. Avoirdupois.
7,000	,,	= 1 lb. ,,
70,000	grains	= 1 gallon (*i.e.*, 1 gallon = 10 lbs.)
36	gallons	= 1 barrel.
1	gallon	= 277·2 cub. inches.
1	,,	= 4·5434 litres.
1	litre	= 1000 cub. centimetres.
1	,,	= 1·7607 pints.
1	,,	= 0·2201 gallons.
1	,,	= 61·027 cub. inches.
1	pint	= 20 fluid oz.
1	,,	= 8750 grains.
1	,,	= 34·66 cub. inches.
1	,,	= 0·567925 litres.
1	barrel	= 163·5644 litres.
1	oz. fluid	= 437·5 grains.

1 oz. fluid = 28·3962 cub. centimetres.
1 metre = 39·37079 inches.
1 inch = 0·02539954 metres.
1 foot = 0·30479449 metres.
1 yard = 0·91438348 metres.
1 septem = 7 grains measure.

PART II.

USEFUL HINTS.

To convert "grams per litre" into "grains per gallon," multiply by 70. To convert "grains per gallon" into "grams per litre," divide by 70. The reason of this is that "grains per gallon" are really "parts in 70,000," and "grams per litre" are parts in 1000.

The "weight" in pounds of a barrel of wort, divided by 360 (*i.e.*, the weight of an equal bulk of water), gives the specific gravity. Thus: If a wort weighs 30 lbs., this means that 36 gallons of it weigh 30 lbs. more than 36 gallons of water. The barrel weighs therefore 390 lbs., and 390 ÷ 360 = 1·0833 the specific gravity.

To convert degrees Centigrade into degrees Fahrenheit, multiply by 9, divide by 5, and add 32.

Thus: Convert 60° C. into degrees F.

60 × 9 = 540 ÷ 5 = 108 + 32 = 140. *Ans.* 140° F.

To convert degrees Fahrenheit into degrees Centigrade, subtract 32, multiply by 5, and divide by 9.

Thus: Convert 60° F. into degrees C.

$60 - 32 = 28 \times 5 = 140 \div 9 = 15{\cdot}5$. *Ans.* 15·5° C.

To find the weight in grams of any given bulk of a liquid, multiply the bulk expressed in cub. cents. by the specific gravity.

To convert per centage of absolute alcohol by weight into per centage by volume, multiply the per centage by weight by the specific gravity, and divide the product by 0·7938.

To convert per centage of absolute alcohol by volume into per centage by weight, divide 0·79461 by the specific gravity, and multiply the product by the per centage by volume.

To convert per centage of proof-spirit into per centage of absolute alcohol by volume, divide the per centage of proof-spirit by 1·7525.

To convert per centage of absolute alcohol by volume into per centage of proof-spirit, multiply the per centage of absolute alcohol by volume by 1·7525.

To convert per centage of proof-spirit into per centage of

absolute alcohol by weight, multiply the per centage of proof-spirit by 0.46154 (approximative).

To find the actual weight of a given bulk of any substance, either solid or liquid, multiply the weight of an equal bulk of water by the specific gravity of the substance.

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